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January 11, 2016

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SUBJ: CPSC staff's comments for the UL 2201 "Standard for Portable Engine-Generator Assemblies" CO Task Group, Subgroup for Emissions Test Method Development, concerning referenced PGMA correspondence

REF: Letter dated December 17, 2015, from PGMA to Kevin Dunn, Subject: "PGMA Comments on "Draft Test Method for UL 2201 Task Group for Determining CO Emission Rate of Portable Generators" "

Dear Dr. Dunn:

This letter contains comments of the staff of the U.S. Consumer Product Safety Commission ("CPSC," "Commission") regarding the referenced document, which was presented by Joe Harding of the Portable Generator Manufacturers Association ("PGMA") on December 18, 2015, at a meeting of Underwriters Laboratories Inc. ("UL") UL 2201 carbon monoxide ("CO") task subgroup for developing an emissions test method.[a] At that meeting, Mr. Harding requested that subgroup members submit their comments on this document[b] to him by January 12, 2016, so that PGMA's technical committee could review the comments at their meeting on January 14, 2016, and be prepared to discuss their responses to the comments at the next meeting of the subgroup, which is scheduled for January 22.

The following are CPSC staff's comments:

1. In PGMA's cover letter, attachment 1 page 1, PGMA states: "we are not aware of any evidence that reduced oxygen levels have played a role in any portable generator related CO incident to date." Research conducted by the National Institute of Standards and Technology ("NIST"), under an interagency agreement with CPSC, involved measuring

[a] These comments are those of CPSC staff, and they have not been reviewed or approved by, and may not necessarily reflect the views of, the Commission.
[b] PGMA's document is a mark-up of a CPSC staff document presented to the UL task subgroup on February 18, 2015, which is listed as reference 1. Staff drafted that document to address subgroup members' comments, concerns, and suggestions on the originally proposed test method that was developed by NIST. NIST's test method is documented in reference 2.

oxygen levels in a 20-foot by 20-foot attached garage during tests while a portable generator was operated in it (see reference 3). In all four tests in which the garage bay door was fully closed, the measured oxygen level in the garage dropped substantially below ambient, which is 20.9 percent oxygen. In two of those tests, the connecting door to the house was closed and the garage oxygen level dropped to nearly 16 percent. In the other two tests, in which the connecting door was opened approximately 2 inches to simulate the passage into the house of an extension cord connected to the generator, the garage oxygen level dropped to between 17.0 percent and 17.5 percent.

Given that the majority of fatal incidents reported to CPSC occurred when the generator was operated in a garage or various other enclosed spaces inside the house (see reference 4), where leakage rates and room volumes could likely result in similar oxygen levels as those achieved in NIST's garage, it is reasonable to conclude that oxygen depletion occurred even though oxygen levels have not been measured during consumer generator-related CO incidents. Considering these data in conjunction with NIST's single-zone shed tests that showed the generator's CO emission rate rises to a peak rate as the oxygen drops to the 17.0 to 17.5 percent oxygen range, CPSC staff recommends that throughout the document where PGMA proposes the emission rate to be measured when the oxygen in the intake air is in the 18.0 to 18.5 percent range, the range should be changed to 17.0 to 17.5 percent.

2. Additionally, in PGMA's cover letter, PGMA explains that PGMA's proposal provides options for emission testing the engine, both while the engine is installed in and electrically loaded through the generator, and while the engine is installed on and mechanically loaded by a dynamometer. At the same time, however, PGMA expresses concern about the reproducibility of the results of this testing. Staff cautions that PGMA's proposal for configuration-dependent loads[c] that would be applied to the engine when the emissions are measured would not give reproducible results because two configuration-dependent methods to determine loads to apply to the engine would yield different load points and thus, different emissions.

The simplest, and perhaps only, way to expect the same results between the two configurations is to require the loads for the generator configuration to be based on maximum generator power, not rated generator power. Subgroup members have discussed during subgroup meetings that generators commonly can be loaded above their rated power, up to the point where the engine is loaded to its maximum power. PGMA members, Honda and Techtronic Industries ("TTi"), proposed basing loads on maximum generator power in subgroup meetings held in August 2015 and December 2015, when each presented their comments on CPSC staff's original version of the document on which PGMA provides these comments, and which is listed as reference 1. TTi's and Honda's presentations are provided in attachments 2 through 5.

If PGMA intends that the different test methods PGMA proposes to measure the emissions are to be reproducible, as was expressed by a subgroup member during the December 18, 2015 meeting, then it is unclear to staff how the emission rates between the two different configurations will equate to one another and how both configurations could be used to meet the same performance requirement. If the subgroup decides to consider different

[c] The load points PGMA proposes are a function of generator's rated load for the generator configuration and a function of maximum engine power for the engine-dynamometer configuration.

performance requirements for the two different configurations, it is also unclear to staff what the basis will be for concluding equivalent levels of stringency for those performance requirements.

3. As a related comment, in section 3.2.2, staff recommends changing the load points from those relative to the generator's output power rating, to those relative to the generator's maximum power and adding a section for a procedure to determine maximum generator power. Both Honda and TTi have proposed ways to determine maximum generator power. In attachment 5, Honda references a draft version of ISO 8528-8, "Reciprocating Internal Combustion Engine Driven Alternating Current Generating Sets -- Part 8: Requirements and Tests for Low-Power Generating Sets." In addition, Honda describes a procedure in attachment 4 for which Honda has been granted approval by the U.S. Environmental Protection Agency ("EPA") to certify some of Honda's generator engines to EPA emissions regulations. Per Honda, Honda can only operate some of Honda's generator engines while installed in the generator, not on a dynamometer. TTi proposes in attachment 3 specific language for a procedure to determine the generator's maximum continuous output power. CPSC staff recommends that the subgroup use the information provided by TTi and Honda to develop a procedure to determine maximum generator power.

4. Regarding PGMA's proposal in sections 3.1.7, 3.3, and 3.6 to use an exhaust recirculation chamber for measuring emissions, in the original version of the document (reference 1), CPSC staff proposed using this chamber as a test structure to determine the ability of the fuel control system ("FCS") on the generator's engine to control Lambda as oxygen drops. This proposal was included to accommodate subgroup members' recommendations to have a test that only the FCS supplier would need to perform that verifies the FCS functions independently of the oxygen level in the intake air so that generator manufacturers and engine manufacturers would not need to conduct emission testing in reduced oxygen on any generator that is equipped with a satisfactorily performing FCS.

After Honda and TTi presented comments in August that reflected both manufacturers had tested their generators in reduced oxygen, staff suggested deleting the proposed requirements in then-sections 3, 4, and 5; therefore, CPSC staff concurs with PGMA about deleting those sections of the document, but CPSC staff emphasizes that deleting those sections includes deleting the exhaust recirculating chamber. Staff notes, however, that PGMA is now proposing to use the chamber to measure CO emission rates, which is not the use CPSC staff intended for the chamber. Using the chamber for that purpose reintroduces many of the subgroup's concerns about costly infrastructure upgrades that would be required with the originally proposed chamber test method developed by NIST (reference 2), such as a means to safely vent the exhaust from the chamber, which is not addressed in PGMA's proposal.

In addition, a Constant Volume Sampling ("CVS") emission measurement system cannot be used in this test method because all of the exhaust must be captured for an accurate reading. While a raw gas emission measurement system could possibly be used, Honda recommends against using raw gas emission measurements in attachment 2 because of the likelihood that generators with catalysts will show lower CO emissions when using the raw gas method compared to the CVS method.

Lastly, PGMA's proposal has no temperature control requirements on the exhaust recirculation chamber. In numerous previous subgroup meetings, subgroup members expressed concern about reproducibility and repeatability of results obtained from using a test method that does not control temperature while the emissions are being measured. For these reasons, CPSC staff recommends deleting sections 3.1.7, 3.3, and 3.6 as well as the option to use a raw gas emission measurement system in section 3.1.4.

5. In sections 3.2, 3.4, 3.5, and 3.7, CPSC staff recommends adding steps to control temperature while the emissions are being measured. CPSC staff added provisions to control temperature in the dilution chamber described in reference 5, which CPSC staff presented to the subgroup in October 2015, largely because of subgroup members' concerns about reproducibility and repeatability of results when there is no temperature control while the emissions are being measured. In these same sections, CPSC staff also recommends adding steps to reduce the oxygen to the 17.0 to 17.5 percent range over a minimum of two minutes and, as recommended by Honda in attachment 2 and by CPSC staff in reference 5, to restore the intake oxygen level back to ambient between loads. The latter point has been an area of concern among several subgroup members because the achievable load in low oxygen often differs from the achievable load at ambient. All load points should be established during normal operating conditions to promote repeatability.

In addition, CPSC staff recommends adding steps to record the intake air oxygen level and temperature during the test; and for sections 3.4 and 3.7, in particular, CPSC staff recommends recording the CO concentration within the dilution chamber. CPSC staff recommends allowing a CO concentration up to 200 ppm in the dilution chamber during the test. Higher levels may indicate a sizeable exhaust leak, which will impact accuracy of the calculated CO emission rate.

6. Regarding the dilution tunnel referenced in sections 3.1.5, 3.2, and 3.5, staff notes that Honda found the dilution tunnel created a vacuum where it was connected to the intake of Honda's small carbureted generator and observed that it made a non-negligible impact. Given this, Honda injected nitrogen directly into the air cleaner chamber instead of using the dilution tunnel (see attachment 2). Staff recommends that the subgroup take Honda's findings into consideration to include the dilution tunnel in the document.

7. Following section 3.7.4, CPSC staff recommends inserting a step for repeating the test for each of the loads listed in section 3.2.2, which staff recommends should be based on maximum generator power, as stated in item 3 above.

8. In sections 3.2.6, 3.4.6, 3.5.6, and 3.7.5, CPSC staff recommends clarifying the procedures to indicate that emissions must be measured for at least 2 minutes at the lowest oxygen level attained just before shut down occurred.

Thank you for the opportunity to provide these comments. We look forward to discussing them with the UL 2201 CO task subgroup.

Sincerely,

Janet L. Buyer

Janet Buyer
Mechanical Engineer
Portable Generator Project Manager

Matt J Brookman

Matthew J. Brookman, P.E.
Mechanical / Fire Protection Engineer

Cc: Joe Harding, PGMA Technical Director
Scott Heh, CPSC Acting Voluntary Standards Coordinator

Attachments:

(1) PGMA letter dated December 17, 2015 to Kevin Dunn, Subject: "PGMA Comments on "Draft Test Method for UL 2201 Task Group for Determining CO Emission Rate of Portable Generators," " presented by Mr. Joe Harding of PGMA to UL 2201 CO task subgroup for emissions test method, at December 18, 2015 subgroup meeting.

(2) Honda submission, "Honda Analysis of the Dilution Tunnel Test," to UL 2201 CO task subgroup for emissions test method meeting, presented by Ms. Sarah Somorai of Honda, at August 12, 2015 subgroup meeting.

(3) Techtronic Industries ("TTi") submission, "TTi Proposed Dilution Chamber Test Method," to UL 2201 CO task subgroup for emissions test method development, presented by Mr. Michael Gardner of TTi, at December 1, 2015 subgroup meeting.

(4) Honda submission, "Emission Test Using a Load Bank," to UL 2201 CO task subgroup for emissions test method development, presented by Ms. Sarah Somorai of Honda, at December 1, 2015 subgroup meeting.

(5) Honda submission, "Honda's Method of Max Generator Power," to UL 2201 CO task subgroup for emissions test method meeting, presented by Ms. Sarah Somorai of Honda, at December 1, 2015 subgroup meeting.

References:

(1) CPSC staff document, *Draft Test Method for UL 2201 Task Group for Determining CO Emission Rate of Portable Generators*, February 17, 2015. http://www.cpsc.gov/Global/Regulations-Laws-and-Standards/Voluntary-Standards/Portable-Generators/Draft-Test-Method-for-Determining-the-CO-Emission-Rate-of-Portable-Generators.pdf

(2) Emmerich, S.J., A. K. Persily, NIST Technical Note 1834: *Development of a Test Method to Determine Carbon Monoxide Emission Rates from Portable Generators*, June 2014. http://www.cpsc.gov/Global/Research-and-Statistics/Technical-Reports/Home/Portable-Generators/NISTReportDevelopmentofaTestMethodtoDetermineCarbonMonoxideEmissionRatesfromPortableGenerators-NISTTechnicalNote1834.pdf

(3) Emmerich, S. J., et al., NIST Technical Note 1781: *Modeling and Measuring the Effects of Portable Gasoline-Powered Generator Exhaust on Indoor Carbon Monoxide Level*, February 2013. http://www.cpsc.gov/Global/Research-and-Statistics/Technical-Reports/Home/Portable-Generators/PortableGenerators041213.pdf

(4) Hnatov, Matthew, *Incidents, Deaths, and In-Depth Investigations Associated with Non-Fire Carbon Monoxide from Engine-Driven Generators and Other Engine-Driven Tools, 2004-2013*, June 2014. http://www.cpsc.gov/Global/Research-and-Statistics/Technical-Reports/Home/Portable-Generators/GeneratorsandOEDTFatalities-2014-FINAL.pdf

(5) Brookman, Matthew, *CPSC Staff Proposal for Determining Carbon Monoxide Emissions from Portable Generators in a Reduced Oxygen Environment Using the Dilution Chamber Method*, October 15, 2015. http://www.cpsc.gov/PageFiles/99044/CPSCStaffLettertoK.DunnforUL2201TaskGroupDiscussionofDilutionChamberTestMethod.pdf

Portable Generator Manufacturers' Association

Secretary/Treasurer:
THOMAS ASSOCIATES, INC.

December 17, 2015

Mr. Kevin Dunn
Chairman
UL 2201 CO Task Group

Via Email: kfd5@cdc.gov

SUBJECT: PGMA Comments on "Draft Test Method for UL 2201 Task Group for Determining CO Emission Rate of Portable Generators"

Dear Kevin:

Attached please find PGMA's comments on the document entitled "Draft Test Method for UL 2201 Task Group for Determining CO Emission Rate of Portable Generators" that was originally circulated to the Hybrid Test Subgroup (now known as the Emissions Test Subgroup) on February 17, 2015. Our comments are shown in both a "tracked" version as well as a "clean" version.

Please note that the attached comments are subject to the following:

- PGMA is concerned about requiring CO emission testing at reduced oxygen levels, since we are not aware of any evidence that reduced oxygen levels have played a role in any portable generator related CO incident to date.
- Although we are in favor of providing several options for testing (i.e. portable generator assembly vs. engine only testing, dilution tunnel method, exhaust recirculation method and dilution chamber method), more work needs to be done to ensure the repeatability and reproducibility of these different options.

We look forward to discussing these comments during a future conference call.

Sincerely,

Joseph Harding

JOSEPH HARDING
Technical Director

JH/jlb
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Attachments

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PGMA Comments (Tracked) - Draft Test Method for UL 2201 Task Group for Determining CO Emission Rate of Portable Generators~~1~~

1. Purpose

~~This document provides test methods to determine the carbon monoxide (CO) emission rate of a portable generator. The appropriate method is determined by the impact of a reduced oxygen environment on the engine's CO emission rate. Test methods and requirements for documentation are also provided to make this determination.~~

This document provides test methods to determine the carbon monoxide (CO) emission rate of a portable generator or portable generator engine in a reduced oxygen environment. The appropriate test method is determined by the engine or equipment manufacturer. Test methods and requirements for documentation are also provided.

2. Scope

~~The following requirements apply to spark-ignited, engine-driven portable generators with rated continuous power up to, and including, 15 kilowatts (kW).~~

The following requirements apply to spark-ignited engines installed in portable generators that are addressed in ANSI/PGMA G300, *Safety and Performance of Portable Generators*. The CO emission rate can be determined by the manufacturer of the engine tested separately of the portable generator or tested as a completed product. The CO emission rate is to be determined in a reduced oxygen environment by using either a dilution tunnel, an exhaust recirculation chamber or a dilution chamber.

~~3. Determining the Oxygen Dependence of a Portable Generator's CO Emission Rate~~

~~3.1 A portable generator is oxygen independent if the conditions in Sections 3.1.1, 3.1.2, and 3.1.3 are satisfied. Its modal CO emission rates must be determined using one of the two test methods specified in Section 5. The generator's weighted CO emission rate and its power-specific weighted CO emission rate are then determined using the calculations provided in Section 7. The power-specific weighted CO emission rate must meet the performance requirement specified in Section 8.~~

~~3.1.1 The manufacturer of either the engine's fuel control system or the generator must provide documentation demonstrating that the fuel control system maintains an air-to-fuel equivalence ratio (λ) of 1 ± 0.05 λ, while operating in closed loop, when tested to one of the methods specified in Section 4. A fuel control system that meets this performance requirement is considered to be an oxygen-independent fuel control system.~~

~~3.1.2 The manufacturer of either the generator's engine or the generator must provide documentation stating the maximum power the engine can deliver while operating in closed loop. This power limit is the maximum load that can be applied continuously to the engine when used in a portable generator.~~

~~[1] This draft test method was prepared by the CPSC staff, and has not been reviewed or approved by, and may not necessarily reflect the views of, the Commission.~~

~~3.1.3 The generator manufacturer must provide documentation stating that the generator assembly is designed to prevent continuous engine operation above the power limit specified by the engine manufacturer for closed-loop operation. Open loop engine operation must only occur during engine warm-up and transient conditions. This documentation must include the size and efficiency of the alternator and the size and performance characteristics of the generator's circuit breaker.~~

~~3.2 A portable generator that does not satisfy the conditions stated in Section 3.1 is oxygen dependent. Its modal CO emission rates must be determined using the test method specified in Section 6. The generator's weighted CO emission rate and its power-specific weighted CO emission rate are then determined using the calculations provided in Section 7. The power-specific weighted CO emission rate must meet the performance requirement specified in Section 8.~~

~~4. Test Method to Determine the Oxygen Dependence of the Fuel Control System~~

~~The fuel control system manufacturer can choose one of two test methods to evaluate the relationship of λ to the engine intake oxygen concentration. The results of either test will determine if the fuel control system is oxygen dependent.~~

~~Note to Task Group: Due to concerns expressed about using a small test chamber in the test method in Section 4.1 in laboratory facilities not configured with an exhaust hood, CPSC staff is proposing an alternative test method in Section 4.2. This alternative test method uses an intake oxygen dilution system, rather than recirculating exhaust, to reduce the oxygen in the intake air to 16.0%. Since this system is under development, the test equipment and procedures are not yet fully defined.~~

~~4.1 Chamber Test Method~~

~~4.1.1 Test Equipment~~

~~4.1.1.1 Test Chamber: The test chamber is a single-zone enclosure capable of reducing oxygen passively to 16 percent oxygen by volume within 2 to 10 minutes by recirculating the exhaust emissions from the test engine within the chamber. Forced ventilation and temperature management are not required. Mixing is naturally driven by the test engine exhaust flow, creating oxygen reduction at the engine intake that is consistent and repeatable. Small variable diameter ports may be used to aid with ventilation adjustments to control the rate of oxygen depletion. For an example of engine displacement versus chamber volume, a nominally 3.5 cubic meter chamber with a nominally 700 cubic centimeter (cc) four stroke, two cylinder engine is capable of reducing oxygen to 16 percent by volume between 1.5 and 5 minutes, depending on load.~~

~~4.1.1.2 Dynamometer: Engine power is measured using an absorption dynamometer at a minimum sample frequency of 1 hertz (Hz).~~

~~4.1.1.3 Gas and Environmental Measurement Systems: Oxygen concentration and temperature are measured at the engine intake with a minimum sample frequency of 1 Hz. λ is measured in the exhaust stream with a minimum sample frequency of 60 Hz.~~

~~4.1.2 Test Procedures~~

~~4.1.3 Start the engine and warm to operating temperature using recommendations in 40 C.F.R. § 1065.510, allowing sufficient ventilation to maintain normal ambient oxygen levels at the engine intake.~~

~~4.1.4 Shut down the engine and adjust the test chamber as needed to reduce oxygen to 16 percent oxygen by volume within 2 to 10 minutes of starting the test engine.~~

~~4.1.5 Start the engine, achieve design engine speed, and apply 50 percent of the engine's rated load within 10 seconds of starting.~~

~~4.1.6 Operate the test until the oxygen concentration is reduced to 16 percent oxygen by volume or the engine stops running.~~

~~4.1.7 Repeat the test two times.~~

~~4.1.8 Perform the calculation procedure specified in Section 4.3.~~

~~4.2 Intake Oxygen Dilution Test Method~~

~~4.2.1 Test Equipment~~

~~4.2.1.1 Dilution Tunnel: The dilution tunnel is a tube connected to the engine intake that is long enough to provide a well-mixed combination of air and bottled nitrogen. The tunnel is large enough in diameter to provide unimpeded flow of the mixture into the intake. Nitrogen for dilution is injected at the far end from the engine intake. Oxygen is measured near the intake to verify the concentration provided to the engine.~~

~~4.2.1.2 Nitrogen Injection System: The nitrogen injection system is capable of providing a variable volume of nitrogen to the intake of the engine to reduce the intake oxygen concentration to 16 percent oxygen by volume while the engine is at operating speed. A control system may be used that references the intake oxygen measurement and properly adjusts the nitrogen injection.~~

~~4.2.1.3 Dynamometer: Engine power is measured using an absorption dynamometer at a minimum sample frequency of 1 hertz (Hz).~~

~~4.2.1.4 Gas and Environmental Measurement Systems: Oxygen concentration is measured at the engine intake with a minimum sample frequency of 1 Hz. λ is measured in the exhaust stream with a minimum sample frequency of 60 Hz.~~

~~4.2.2 Test Procedures~~

~~4.2.2.1 Start the engine and warm to operating temperature using recommendations in 40 C.F.R. § 1065.510 with undiluted air.~~

~~4.2.2.2 Apply 50 percent of the engine's rated load and begin recording the oxygen concentration and λ.~~

~~4.2.2.3 Reduce the intake oxygen concentration by introducing the nitrogen stream. Reduce oxygen steadily to 16 percent oxygen by volume, measured at the engine intake, over a period of 5 to 10 minutes or until the engine shuts down.~~

~~4.2.2.4 Repeat this test two times.~~

~~4.2.2.5 Perform the calculation procedure specified in Section 4.3.~~

~~4.3 Calculation Procedure~~

~~For each test, calculate the 5-second running mean λ for the test duration after the load is applied. To be oxygen independent, the fuel control system must maintain a mean λ of 1 ± 0.05 λ for all oxygen concentrations down to 16 percent or until the engine shuts down, for all three tests.~~

~~5.~~3. Test Method to Determine the Modal CO emission Rates of a~~n Oxygen-Independent~~ Portable Generator or Portable Generator Engine

~~An oxygen independent portable generator is a portable generator that meets the conditions specified in Section 3.1 To determine the modal CO emission rates of an oxygen-independent portable generator, the generator manufacturer may estimate or determine through testing the CO rates when each of six discrete loads are applied.~~

To determine the CO emission rate of a portable generator or portable generator engine, determine the modal CO emission rates at six discrete generator loads with reduced engine intake oxygen between 18.0 percent and 18.5 percent oxygen by volume.

~~5.1 Estimation Method: Estimate the generator's modal CO emission rates at each of six discrete loads described in section 5.1.1 in ambient oxygen. Calculate the generator's weighted CO emission rate and power-specific weighted CO emission rate using the equations specified in Section 7.~~

~~5.1.1 Using the alternator size and efficiency data, circuit breaker size, and the modal CO rates obtained from the engine's exhaust emission test* required by the U.S. Environmental Protection Agency (EPA) for certification to 40 C.F.R. § 1054, make reasonable estimations of the CO emission rates when the engine is installed in the generator and operating with each of the following six discrete loads on the generator:~~

~~1. Generator mode 1 power: 100 percent of the generator's continuous power rating~~
~~2. Generator mode 2 power: 75 percent of the generator's continuous power rating~~
~~3. Generator mode 3 power: 50 percent of the generator's continuous power rating~~
~~4. Generator mode 4 power: 25 percent of the generator's continuous power rating~~
~~5. Generator mode 5 power: 10 percent of the generator's continuous power rating~~
~~6. Generator mode 6 power: no load applied~~

~~* Note: The EPA allows engine manufacturers to group engines with similar configurations into a single engine family, and the engine configuration in that~~

~~family, which is expected but not necessarily known to have the highest hydrocarbon and oxides of nitrogen (HC+NOx) emission rate, is to be used for certification of the entire family to 40 C.F.R. § 1054. Notably, the engine in the generator may not be the same as the engine on which the certification test was performed.~~

~~5.1.2 Perform the calculation procedure in Section 7, using the modal CO emission rates estimated in Section 5.1.1, to determine the generator's weighted CO emission rate and power specific weighted CO emission rate.~~

~~5.2 Measurement method: Determine the generator's modal CO emission rates at each of six loads in ambient oxygen.~~

~~5.3 Test Equipment~~

~~5.3.1 Load bank and power meter: An AC electric resistor load bank is used to simulate steady electric loads on the generator. The load bank is capable of adjustment to within 5 percent of each required load condition. A power meter is used to measure the actual electrical load delivered by the generator with an accuracy of 5 percent.~~

~~5.3.2 Fuel and lubricants: Fuel and lubricants for this test must meet manufacturer's specifications for the generator being tested.~~

~~5.3.3 Emission measurement system: A constant volume sampling (CVS) or raw gaseous emission measurement system must meet the requirements of 40 C.F.R. § 1065.~~

~~5.3.4 Test Procedures~~

~~5.3.4.1 Establish and maintain intake air temperature of 20 °C ± 10 °C and relative humidity of 50 percent ± 15 percent RH.~~

~~5.3.4.2 Connect the load bank to the generator's receptacle.~~

~~5.3.4.3 Start the generator and warm to operating temperature using recommendations in 40 C.F.R. § 1065.510.~~

~~5.3.4.4 With the generator still running, adjust the load bank to apply the first load listed in Section 5.1.1.~~

~~5.3.4.5 After at least 5 minutes of stable operation with the prescribed load applied, sample emissions for at least 1 minute using the emission measurement system, then stop emission sampling. Record the mean CO emission values for that load, then adjust the load bank to apply the next load listed in Section 5.1.1.~~

~~5.3.4.6 Repeat step 5.2.2.5 for all six loads.~~

~~5.3.4.7 Determine the modal CO emission rate at each of the 6 loads using calculations consistent with those provided in 40 C.F.R. § 1065.~~

~~5.3.4.8 Perform the calculation procedure in Section 7, using the modal CO emission rates determined in Section 5.2.2.7, to determine the generator's weighted CO emission rate and power specific weighted CO emission rate.~~

~~6. Test Method to Determine the Modal CO emission Rates of an Oxygen Dependent Portable Generator.~~

~~An oxygen-dependent portable generator is a portable generator that does not meet the conditions specified in Section 3.1. To determine the CO emission rate of an oxygen-dependent portable generator, determine the generator's modal CO emission rates at six discrete generator loads with reduced engine intake oxygen between 17.0 percent and 17.5 percent oxygen by volume.~~

~~Note to Task Group: This test method is provided in the event it is found that the relationship of a generator's peak CO emission rate at reduced oxygen relative to the CO emission rate at ambient is not consistent among a variety of portable generator sizes (discussed within the Task Group as a "common factor" for the increase in CO emission rate). For this test, CPSC staff proposes to use the intake oxygen dilution system described in Section 4.2 to reduce the oxygen in the intake. This will allow manufacturers to use their current exhaust emission measurement equipment to determine CO emission rates instead of the NIST proposed chamber test method. The intake oxygen dilution system is under development; therefore, the test equipment and procedures are not yet fully defined.~~

~~6.1~~3.1 ~~Test Equipment~~Definitions

3.1.1 Load bank and power meter: An AC electric resistor load bank is used to simulate steady electric loads on the generator. The load bank is capable of adjustment to within 5 percent of each required load condition. A power meter is used to measure the actual electrical load delivered by the generator with an accuracy of 5 percent.

~~6.1.1~~3.1.2 Engine Dynamometer: Engine dynamometer must meet the performance specifications of 40 CFR Part 1054 and 1065 as related to spark-ignited engines producing less than 19kW.

~~6.1.2~~3.1.3 Fuel and lubricants: Fuel and lubricants for this test must meet manufacturer's specifications for the generator or engine being tested.

~~6.1.3~~3.1.4 ~~Emission measurement system:~~ Emission measurement system: A constant volume sampling (CVS) or raw gaseous emission measurement system must meet the requirements of 40 CFR Part 1054 and 1065~~40 C.F.R. § 1065~~.

~~6.1.4~~3.1.5 Dilution Tunnel: ~~The dilution tunnel is a~~A tube connected to the engine intake that is long enough to provide a well-mixed combination of air and bottled nitrogen. The tunnel is large enough in diameter to provide unimpeded flow of the mixture into the intake. Nitrogen for dilution is injected at the far end from the engine intake. Oxygen is measured near the intake to verify the concentration provided to the engine.

~~Nitrogen Injection System: The nitrogen injection system is capable of providing a variable volume of nitrogen to the intake of the engine to reduce the intake oxygen concentration to 16 percent oxygen by volume while the engine is at operating speed. A control system may be used that references the intake oxygen measurement and properly adjusts the nitrogen injection.~~

3.1.6 Dilution Chamber: A test fixture that encloses the portable generator or engine and reduces the oxygen level of the air at the engine intake by injecting nitrogen into the volume inside the chamber. The exhaust from the engine does not accumulate in the chamber but is ducted directly out of the engine to a Constant Volume Sampling (CVS) system for analysis.

3.1.7 Exhaust Recirculation Chamber: A single-zone enclosure capable of reducing oxygen passively to 18.0 to 18.5 percent oxygen by volume by recirculating the exhaust emissions from the test engine within the chamber. Mixing is naturally driven by the test engine exhaust flow, creating oxygen reduction at the engine intake that is consistent and repeatable. Small variable diameter ports may be used to aid with ventilation adjustments to control volume during high fuel flow modes.

3.1.8 Shut Down Device: Device that is permanently installed in or on the portable generator or engine that renders the unit inoperable when an undesired condition is met.

3.1.9 O_2 Meter: Meter capable of measuring oxygen from 20.9 – 18.0 % at 1Hz.

3.1.10 CO Meter: Meter capable of measuring CO levels at 1Hz.

3.1.11 Output Power Rating: The output power rating measured in accordance with ANSI/PGMA G300, *Safety and Performance of Portable Generators.*

3.2 Portable Generator Test Procedure - Dilution Tunnel

3.2.1 At an ambient air temperature of 15 - 35 °C (59-95 °F), start the portable generator and warm at any speed and at approximately 75% of its output power rating for 10 minutes.

3.2.2 With the generator still running, adjust the load bank to apply the first load listed below.

1. Generator mode 1 power: 100 % of the portable generator's output power rating
2. Generator mode 2 power: 75 % of the portable generator's output power rating
3. Generator mode 3 power: 50 % of the portable generator's output power rating
4. Generator mode 4 power: 25 % of the portable generator's output power rating
5. Generator mode 5 power: 10 % of the portable generator's output power rating
6. Generator mode 6: No load applied

3.2.3 Reduce oxygen steadily at the engine intake by introducing the nitrogen stream until the oxygen concentration, measured at the engine intake, is between 18.0 percent and 18.5 percent by volume.

3.2.4 While maintaining the oxygen concentration between 18.0 percent and 18.5 percent by volume, sample emissions for at least 2 minutes with the prescribed load applied then stop emission sampling. Record the mean CO emission values for that load.

3.2.5 Repeat this test for each load listed in Section 3.2.2.

3.2.6 If a shut down device is installed in the unit, record the CO emission rate up to the activation of the shut down device. Use that CO emission rate as the modal value in the calculations of section 4.

3.2.7 Determine the modal CO emission rate at each of the 6 loads using calculations consistent with those provided in 40 C.F.R. § 1065.

3.2.8 When each modal result is completed use the calculation of Section 4 to determine the weighted CO emission rate.

3.3 Generator Test Procedure - Exhaust Recirculation Chamber

3.3.1 With the exhaust recirculation chamber open, at an ambient air temperature of 15 - 35 °C (59-95 °F), start the portable generator and warm at any speed at approximately 75% of its output power rating for 10 minutes.

3.3.2 Adjust the load bank to apply the first load listed in Section 3.2.2.

3.3.3 Close the exhaust recirculation chamber and run the portable generator and continuously record the oxygen level of the intake air, the CO emission rate in the exhaust, and time at 1Hz, until the unit reaches an oxygen level between 18.0 and 18.5 percent by volume. The oxygen level must be between 18.0 to 18.5 percent by volume within 2 to 10 minutes of closing the exhaust recirculation chamber. The CO measured at an oxygen level between 18.0 and 18.5 percent by volume is used as the modal value in the calculations of section 4.

3.3.4 If a shut down device is installed in the unit, record the CO emission rate up to the activation of the shut down device. Use that CO emission rate as the modal value in the calculations of section 4.

3.3.5 Shut down the portable generator and open the exhaust recirculation chamber to return the oxygen level to ambient condition.

3.3.6 Repeat each mode twice for each load listed in Section 3.2.2.

3.3.7 Average the results of each mode and then apply the calculations of section 4.

3.4 Generator Test Procedure - Dilution Chamber

3.4.1 With the dilution chamber open, at an ambient air temperature of 15 - 35°C (59-95 ºF), start the portable generator and warm at any speed at approximately 75% of its output power rating for 10 minutes.

3.4.2 Adjust the load bank to apply the first load listed in Section 3.2.2.

3.4.3 With the dilution chamber closed, reduce oxygen steadily at the engine intake by introducing the nitrogen stream into the dilution chamber until the oxygen concentration, measured at the engine intake, is between 18.0 percent and 18.5 percent by volume.

3.4.4 While maintaining the oxygen concentration between 18.0 percent and 18.5 percent by volume, sample emissions for at least 2 minutes with the prescribed load applied then stop emission sampling. Record the mean CO emission values for that load.

3.4.5 Repeat this test for each load listed in Section 3.2.2.

3.4.6 If a shut down device is installed in the unit, record the CO emission rate up to the activation of the shut down device. Use that CO emission rate as the modal value in the calculations of section 4.

3.4.7 Determine the modal CO emission rate at each of the 6 loads using calculations consistent with those provided in 40 C.F.R. § 1065.

3.4.8 When each modal result is completed use the calculation of Section 4 to determine the weighted CO emission rate.

3.5 Engine Test Procedure - Dilution Tunnel

3.5.1 At an ambient air temperature of 15 - 35 °C (59-95 °F), start the engine and warm at any speed and approximately 75% of maximum engine power for 10 minutes.

3.5.2 Adjust the dynamometer to apply the first of the following loads:

1. Engine mode 1 power: 100 % of the maximum engine power .
2. Engine mode 2 power: 75 % of engine mode 1 on governor
3. Engine mode 3 power: 50 % of engine mode 1 on governor
4. Engine mode 4 power: 25 % of engine mode 1 on governor
5. Engine mode 5 power: 10 % of engine mode 1 on governor
6. Engine mode 6: No load applied

3.5.3 Reduce oxygen steadily at the engine intake by introducing the nitrogen stream until the oxygen concentration, measured at the engine intake, is between 18.0 percent and 18.5 percent by volume.

3.5.4 While maintaining the oxygen concentration between 18.0 percent and 18.5 percent by volume, sample emissions for at least 2 minutes with the prescribed load applied then stop emission sampling. Record the mean CO emission values for that load.

3.5.5 Repeat this test for each load listed in Section 3.5.2.

3.5.6 If a shut down device is installed in the unit, record the CO emission rate up to the activation of the shut down device. Use that CO emission rate as the modal value in the calculations of section 4.

3.5.7 Determine the modal CO emission rate at each of the 6 loads using calculations consistent with those provided in 40 C.F.R. § 1065.

3.5.8 When each modal result is completed, use the calculation of Section 4 to determine the weighted CO emission rate.

3.6 Engine Test Procedure - Exhaust Recirculation Chamber

3.6.1 At an ambient air temperature of 15 - 35 °C (59-95 °F) and the exhaust recirculation chamber open , start the engine and warm at any speed at approximately 75% of maximum engine power for 10 minutes.

3.6.2 Adjust the dynamometer to apply the first load listed in Section 3.5.2.

3.6.3 With the exhaust recirculation chamber closed, run the engine and continuously record the oxygen level of the intake air, the CO emission rate in the exhaust, and time at 1Hz, until the unit reaches an oxygen level between 18.0 and 18.5 percent by volume. The oxygen level must be between 18.0 to 18.5 percent by volume within 2 to 10 minutes of closing the exhaust recirculation chamber. The CO measured at an oxygen level between 18.0 and 18.5 percent by volume is used as the modal value in the calculations of section 4.

3.6.4 If a shut down device is installed in the unit, record the CO emission rate up to the activation of the shut down device. Use that CO emission rate as the modal value in the calculations of section 4.

3.6.5 Shut down the engine and open the exhaust recirculation chamber to return the oxygen level to ambient condition.

3.6.6 Repeat this test twice for each load listed in Section 3.5.2.

3.6.7 Average the results of each mode and then apply the calculations of section 4.

3.7 Engine Test Procedure - Dilution Chamber

3.7.1 At an ambient air temperature of 15 - 35°C (59-95 °F) and the dilution chamber open , start the engine and warm at any speed at approximately 75% of maximum engine power for 10 minutes.

3.7.2 With the engine still running and the dilution chamber closed, adjust the dynamometer to apply the first load listed in Section 3.5.2.

3.7.3 Reduce oxygen steadily at the engine intake by introducing the nitrogen stream into the dilution chamber until the oxygen concentration, measured at the engine intake, is between 18.0 percent and 18.5 percent by volume.

3.7.4 While maintaining the oxygen concentration between 18.0 percent and 18.5 percent by volume, sample emissions for at least 2 minutes with the prescribed load applied then stop emission sampling. Record the mean CO emission values for that load.

3.7.5 If a shut down device is installed in the unit, record the CO emission rate up to the activation of the shut down device. Use that CO emission rate as the modal value in the calculations of section 4.

3.7.6 Repeat this test for each load listed in Section 3.5.2.

3.7.7 Determine the modal CO emission rate at each of the 6 loads using calculations consistent with those provided in 40 C.F.R. § 1065.

3.7.8 When each modal result is completed, use the calculation of Section 4 to determine the weighted CO emission rate.

~~6.2 Test Procedures~~

~~6.2.1 Start the engine and warm to operating temperature using recommendations in 40 C.F.R. § 1065.510 with undiluted air.~~

~~6.2.2 With the generator still running, adjust the load bank to apply the first load listed in Section 5.1.1.~~

~~6.2.3 Reduce oxygen steadily at the engine intake by introducing the nitrogen stream until the oxygen concentration, measured at the engine intake, is between 17.0 percent and 17.5 percent by volume.~~

~~6.2.4 While maintaining the oxygen concentration between 17.0 percent and 17.5 percent by volume, sample emissions for at least 1 minute with the prescribed load applied then stop emission sampling. Record the mean CO emission values for that load.~~

~~6.2.5 Shut down the engine and repeat this test for each load listed in Section 5.1.1.~~

~~6.2.6 Determine the modal CO emission rate at each of the 6 loads using calculations consistent with those provided in 40 C.F.R. § 1065.~~

~~6.3 Perform the calculation procedure in Section 7, using the modal CO emission rates determined in Section 6.2.6, to determine the generator's weighted CO emission rate and power-specific weighted CO emission rate.~~

~~7.~~4. Calculation Procedure to Determine the Generator's ~~Weighted CO Emission Rate and Power-Specific~~or Engine's Weighted CO Emission Rate

Calculate the generator's or engine's weighted CO emission rate using the following equation:

$$\dot{m}_W = 0.09 \times \dot{m}_1 + 0.20 \times \dot{m}_2 + 0.29 \times \dot{m}_3 + 0.30 \times \dot{m}_4 + 0.07 \times \dot{m}_5 + 0.05 \times \dot{m}_6$$

where,

$$\dot{m}_W = Weighted\ CO\ Emission\ Rate, gram\ per\ hour\ \left(\frac{g}{hour}\right)$$
$$\dot{m}_1 = CO\ Emission\ Rate\ at\ mode\ 1\ \left(\frac{g}{hour}\right)$$
$$\dot{m}_2 = CO\ Emission\ Rate\ at\ mode\ 2\ \left(\frac{g}{hour}\right)$$
$$\dot{m}_3 = CO\ Emission\ Rate\ at\ mode\ 3\ \left(\frac{g}{hour}\right)$$
$$\dot{m}_4 = CO\ Emission\ Rate\ at\ mode\ 4\ \left(\frac{g}{hour}\right)$$
$$\dot{m}_5 = CO\ Emission\ Rate\ at\ mode\ 5\ \left(\frac{g}{hour}\right)$$
$$\dot{m}_6 = CO\ Emission\ Rate\ at\ mode\ 6\ \left(\frac{g}{hour}\right)$$

~~Calculate the generator's power-specific weighted CO emission rate by dividing the generator's weighted CO emission rate by its rated continuous power, as specified by the generator manufacturer.~~

~~8. Performance Requirement~~

~~Spark-ignited engine-driven portable generators with rated continuous power up to, and including, 15 kW must have a power-specific weighted CO emission rate less than or equal to ___ g/hr per kW of the generator's rated continuous power.~~

PGMA Comments (Clean) - Draft Test Method for UL 2201 Task Group for Determining CO Emission Rate of Portable Generators

1. Purpose

This document provides test methods to determine the carbon monoxide (CO) emission rate of a portable generator or portable generator engine in a reduced oxygen environment. The appropriate test method is determined by the engine or equipment manufacturer. Test methods and requirements for documentation are also provided.

2. Scope

The following requirements apply to spark-ignited engines installed in portable generators that are addressed in ANSI/PGMA G300, *Safety and Performance of Portable Generators*. The CO emission rate can be determined by the manufacturer of the engine tested separately of the portable generator or tested as a completed product. The CO emission rate is to be determined in a reduced oxygen environment by using either a dilution tunnel, an exhaust recirculation chamber or a dilution chamber.

3. Test Method to Determine the Modal CO emission Rates of a Portable Generator or Portable Generator Engine

To determine the CO emission rate of a portable generator or portable generator engine, determine the modal CO emission rates at six discrete generator loads with reduced engine intake oxygen between 18.0 percent and 18.5 percent oxygen by volume.

3.1 Definitions

3.1.1 Load bank and power meter: An AC electric resistor load bank is used to simulate steady electric loads on the generator. The load bank is capable of adjustment to within 5 percent of each required load condition. A power meter is used to measure the actual electrical load delivered by the generator with an accuracy of 5 percent.

3.1.2 Engine Dynamometer: Engine dynamometer must meet the performance specifications of 40 CFR Part 1054 and 1065 as related to spark-ignited engines producing less than 19kW.

3.1.3 Fuel and lubricants: Fuel and lubricants for this test must meet manufacturer's specifications for the generator or engine being tested.

3.1.4 Emission measurement system: A constant volume sampling (CVS) or raw gaseous emission measurement system must meet the requirements of 40 CFR Part 1054 and 1065.

3.1.5 Dilution Tunnel: A tube connected to the engine intake that is long enough to provide a well-mixed combination of air and bottled nitrogen. The tunnel is large enough in diameter to provide unimpeded flow of the mixture into the intake. Nitrogen for dilution is injected at the far end from the engine intake. Oxygen is measured near the intake to verify the concentration provided to the engine.

3.1.6 Dilution Chamber: A test fixture that encloses the portable generator or engine and reduces the oxygen level of the air at the engine intake by injecting nitrogen into the volume inside the chamber. The exhaust from the engine does not accumulate in the chamber but is ducted directly out of the engine to a Constant Volume Sampling (CVS) system for analysis.

3.1.7 Exhaust Recirculation Chamber: A single-zone enclosure capable of reducing oxygen passively to 18.0 to 18.5 percent oxygen by volume by recirculating the exhaust emissions from the test engine within the chamber. Mixing is naturally driven by the test engine exhaust flow, creating oxygen reduction at the engine intake that is consistent and repeatable. Small variable diameter ports may be used to aid with ventilation adjustments to control volume during high fuel flow modes.

3.1.8 Shut Down Device: Device that is permanently installed in or on the portable generator or engine that renders the unit inoperable when an undesired condition is met.

3.1.9 O_2 Meter: Meter capable of measuring oxygen from 20.9 – 18.0 % at 1Hz.

3.1.10 CO Meter: Meter capable of measuring CO levels at 1Hz.

3.1.11 Output Power Rating: The output power rating measured in accordance with ANSI/PGMA G300, *Safety and Performance of Portable Generators.*

3.2 Portable Generator Test Procedure - Dilution Tunnel

3.2.1 At an ambient air temperature of 15 - 35 °C (59-95 °F), start the portable generator and warm at any speed and at approximately 75% of its output power rating for 10 minutes.

3.2.2 With the generator still running, adjust the load bank to apply the first load listed below.

1. Generator mode 1 power: 100 % of the portable generator's output power rating
2. Generator mode 2 power: 75 % of the portable generator's output power rating
3. Generator mode 3 power: 50 % of the portable generator's output power rating
4. Generator mode 4 power: 25 % of the portable generator's output power rating
5. Generator mode 5 power: 10 % of the portable generator's output power rating
6. Generator mode 6: No load applied

3.2.3 Reduce oxygen steadily at the engine intake by introducing the nitrogen stream until the oxygen concentration, measured at the engine intake, is between 18.0 percent and 18.5 percent by volume.

3.2.4 While maintaining the oxygen concentration between 18.0 percent and 18.5 percent by volume, sample emissions for at least 2 minutes with the prescribed load applied then stop emission sampling. Record the mean CO emission values for that load.

3.2.5 Repeat this test for each load listed in Section 3.2.2.

3.2.6 If a shut down device is installed in the unit, record the CO emission rate up to the activation of the shut down device. Use that CO emission rate as the modal value in the calculations of section 4.

3.2.7 Determine the modal CO emission rate at each of the 6 loads using calculations consistent with those provided in 40 C.F.R. § 1065.

3.2.8 When each modal result is completed use the calculation of Section 4 to determine the weighted CO emission rate.

3.3 Generator Test Procedure - Exhaust Recirculation Chamber

3.3.1 With the exhaust recirculation chamber open, at an ambient air temperature of 15 - 35 °C (59-95 °F), start the portable generator and warm at any speed at approximately 75% of its output power rating for 10 minutes.

3.3.2 Adjust the load bank to apply the first load listed in Section 3.2.2.

3.3.3 Close the exhaust recirculation chamber and run the portable generator and continuously record the oxygen level of the intake air, the CO emission rate in the exhaust, and time at 1Hz, until the unit reaches an oxygen level between 18.0 and 18.5 percent by volume. The oxygen level must be between 18.0 to 18.5 percent by volume within 2 to 10 minutes of closing the exhaust recirculation chamber. The CO measured at an oxygen level between 18.0 and 18.5 percent by volume is used as the modal value in the calculations of section 4.

3.3.4 If a shut down device is installed in the unit, record the CO emission rate up to the activation of the shut down device. Use that CO emission rate as the modal value in the calculations of section 4.

3.3.5 Shut down the portable generator and open the exhaust recirculation chamber to return the oxygen level to ambient condition.

3.3.6 Repeat each mode twice for each load listed in Section 3.2.2.

3.3.7 Average the results of each mode and then apply the calculations of section 4.

3.4 Generator Test Procedure - Dilution Chamber

3.4.1 With the dilution chamber open, at an ambient air temperature of 15 - 35°C (59-95 ºF), start the portable generator and warm at any speed at approximately 75% of its output power rating for 10 minutes.

3.4.2 Adjust the load bank to apply the first load listed in Section 3.2.2.

3.4.3 With the dilution chamber closed, reduce oxygen steadily at the engine intake by introducing the nitrogen stream into the dilution chamber until the oxygen concentration, measured at the engine intake, is between 18.0 percent and 18.5 percent by volume.

3.4.4 While maintaining the oxygen concentration between 18.0 percent and 18.5 percent by volume, sample emissions for at least 2 minutes with the prescribed load applied then stop emission sampling. Record the mean CO emission values for that load.

3.4.5 Repeat this test for each load listed in Section 3.2.2.

3.4.6 If a shut down device is installed in the unit, record the CO emission rate up to the activation of the shut down device. Use that CO emission rate as the modal value in the calculations of section 4.

3.4.7 Determine the modal CO emission rate at each of the 6 loads using calculations consistent with those provided in 40 C.F.R. § 1065.

3.4.8 When each modal result is completed use the calculation of Section 4 to determine the weighted CO emission rate.

3.5 Engine Test Procedure - Dilution Tunnel

3.5.1 At an ambient air temperature of 15 - 35 °C (59-95 °F), start the engine and warm at any speed and approximately 75% of maximum engine power for 10 minutes.

3.5.2 Adjust the dynamometer to apply the first of the following loads:

1. Engine mode 1 power: 100 % of the maximum engine power .
2. Engine mode 2 power: 75 % of engine mode 1 on governor
3. Engine mode 3 power: 50 % of engine mode 1 on governor
4. Engine mode 4 power: 25 % of engine mode 1 on governor
5. Engine mode 5 power: 10 % of engine mode 1 on governor
6. Engine mode 6: No load applied

3.5.3 Reduce oxygen steadily at the engine intake by introducing the nitrogen stream until the oxygen concentration, measured at the engine intake, is between 18.0 percent and 18.5 percent by volume.

3.5.4 While maintaining the oxygen concentration between 18.0 percent and 18.5 percent by volume, sample emissions for at least 2 minutes with the prescribed load applied then stop emission sampling. Record the mean CO emission values for that load.

3.5.5 Repeat this test for each load listed in Section 3.5.2.

3.5.6 If a shut down device is installed in the unit, record the CO emission rate up to the activation of the shut down device. Use that CO emission rate as the modal value in the calculations of section 4.

3.5.7 Determine the modal CO emission rate at each of the 6 loads using calculations consistent with those provided in 40 C.F.R. § 1065.

3.5.8 When each modal result is completed, use the calculation of Section 4 to determine the weighted CO emission rate.

3.6 Engine Test Procedure - Exhaust Recirculation Chamber

3.6.1 At an ambient air temperature of 15 - 35 °C (59-95 °F) and the exhaust recirculation chamber open , start the engine and warm at any speed at approximately 75% of maximum engine power for 10 minutes.

3.6.2 Adjust the dynamometer to apply the first load listed in Section 3.5.2.

3.6.3 With the exhaust recirculation chamber closed, run the engine and continuously record the oxygen level of the intake air, the CO emission rate in the exhaust, and time at 1Hz, until the unit reaches an oxygen level between 18.0 and 18.5 percent by volume. The oxygen level must be between 18.0 to 18.5 percent by volume within 2 to 10 minutes of closing the exhaust recirculation chamber. The CO measured at an oxygen level between 18.0 and 18.5 percent by volume is used as the modal value in the calculations of section 4.

3.6.4 If a shut down device is installed in the unit, record the CO emission rate up to the activation of the shut down device. Use that CO emission rate as the modal value in the calculations of section 4.

3.6.5 Shut down the engine and open the exhaust recirculation chamber to return the oxygen level to ambient condition.

3.6.6 Repeat this test twice for each load listed in Section 3.5.2.

3.6.7 Average the results of each mode and then apply the calculations of section 4.

3.7 Engine Test Procedure - Dilution Chamber

3.7.1 At an ambient air temperature of 15 - 35°C (59-95 °F) and the dilution chamber open , start the engine and warm at any speed at approximately 75% of maximum engine power for 10 minutes.

3.7.2 With the engine still running and the dilution chamber closed, adjust the dynamometer to apply the first load listed in Section 3.5.2.

3.7.3 Reduce oxygen steadily at the engine intake by introducing the nitrogen stream into the dilution chamber until the oxygen concentration, measured at the engine intake, is between 18.0 percent and 18.5 percent by volume.

3.7.4 While maintaining the oxygen concentration between 18.0 percent and 18.5 percent by volume, sample emissions for at least 2 minutes with the prescribed load applied then stop emission sampling. Record the mean CO emission values for that load.

3.7.5 If a shut down device is installed in the unit, record the CO emission rate up to the activation of the shut down device. Use that CO emission rate as the modal value in the calculations of section 4.

3.7.6 Repeat this test for each load listed in Section 3.5.2.

3.7.7 Determine the modal CO emission rate at each of the 6 loads using calculations consistent with those provided in 40 C.F.R. § 1065.

3.7.8 When each modal result is completed, use the calculation of Section 4 to determine the weighted CO emission rate.

4. Calculation Procedure to Determine the Generator's or Engine's Weighted CO Emission Rate

Calculate the generator's or engine's weighted CO emission rate using the following equation:

$$\dot{m}_W = 0.09 \times \dot{m}_1 + 0.20 \times \dot{m}_2 + 0.29 \times \dot{m}_3 + 0.30 \times \dot{m}_4 + 0.07 \times \dot{m}_5 + 0.05 \times \dot{m}_6$$

where,

$\dot{m}_W = \textit{Weighted CO Emission Rate, gram per hour} \left(\frac{g}{hr}\right)$
$\dot{m}_1 = \textit{CO Emission Rate at mode 1} \left(\frac{g}{hr}\right)$
$\dot{m}_2 = \textit{CO Emission Rate at mode 2} \left(\frac{g}{hr}\right)$
$\dot{m}_3 = \textit{CO Emission Rate at mode 3} \left(\frac{g}{hr}\right)$
$\dot{m}_4 = \textit{CO Emission Rate at mode 4} \left(\frac{g}{hr}\right)$
$\dot{m}_5 = \textit{CO Emission Rate at mode 5} \left(\frac{g}{hr}\right)$
$\dot{m}_6 = \textit{CO Emission Rate at mode 6} \left(\frac{g}{hr}\right)$

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The Power of Dreams

Honda Analysis of the Dilution Tunnel Test

August 12, 2015

Introduction

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To further evaluate CPSC's proposed "Draft Test Method for UL 2201 Task Group for Determining CO Emission Rate of Portable Generators," Honda conducted a feasibility study on the dilution tunnel test as prescribed by the test method.

Today, we would like to share our results, concerns and recommendations.

Agenda

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1. Dilution Tunnel Test Overview
2. Definitions
3. Evaluation of Dilution Tunnel Test
4. Evaluation of Emission Calculation Method
5. Recommendations

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1. Dilution Tunnel Test Overview
2. Definitions
3. Evaluation of Dilution Tunnel Test
4. Evaluation of Emission Calculation Method
5. Recommendations

Introduction to the Dilution Tunnel Test

The dilution tunnel test is an alternative to the NIST proposed chamber test. It is presumed to be a safer, more cost effective method.

Nitrogen is introduced into the engine intake via a tunnel or tube. This reduces the O_2 concentration which mimics the real-world scenario of those who inappropriately run a portable generator in an enclosed space.

Honda conducted a feasibility study of the dilution tunnel test on a small carbureted generator and a large fuel-injected generator.

Dilution Tunnel Test Set-up Requirements per Section 4.2

- Tunnel is connected to the engine intake
- Tunnel is long enough to provide a well-mixed combination of air and nitrogen (O_2 is measured at the intake to confirm this)
- Tunnel has a large enough diameter to provide an unimpeded flow
- Nitrogen is injected at the far end of the tunnel
- Goal is to reduce O_2 concentration down to 16%

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Dilution Tunnel Test Procedure per Section 4.2

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- Warm up the engine according to 40 CFR 1065.510
- Apply 50% of engine rated load and start recording O_2 concentration and λ (air-to-fuel equivalence ratio)
- Introduce nitrogen into the system steadily down to 16% O_2 concentration over 5 to 10 minutes
- Repeat test two times

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1. Dilution Tunnel Test Overview
2. Definitions
3. Evaluation of Dilution Tunnel Test
4. Evaluation of Emission Calculation Method
5. Recommendations

Definitions

Clear definitions are needed for the below:

- **Rated Continuous Power** (section 2, 7, 8)
- **Maximum Power** (3.1.2)
- **Engine Rated Load** (4.1.5, 4.2.2.2)
- **Design Engine Speed** (4.1.5)
- **Generator's Continuous Power Rating** (5.1.1)
  *Honda interpreted as max load
- **Operating Speed** (4.2.1.2, 6.1.5)

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Dilution Tunnel Test - Honda's Schematic

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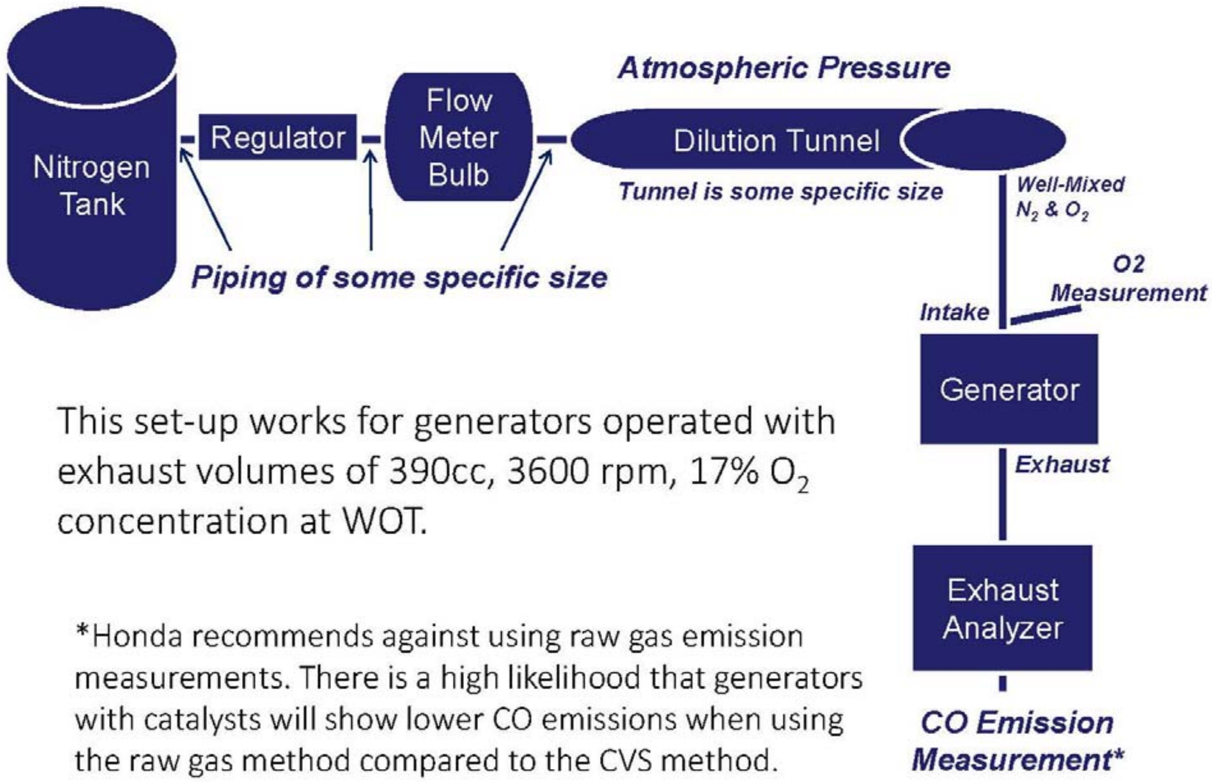

This set-up works for generators operated with exhaust volumes of 390cc, 3600 rpm, 17% O_2 concentration at WOT.

*Honda recommends against using raw gas emission measurements. There is a high likelihood that generators with catalysts will show lower CO emissions when using the raw gas method compared to the CVS method.

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Dilution Tunnel Test - Areas for Improvement

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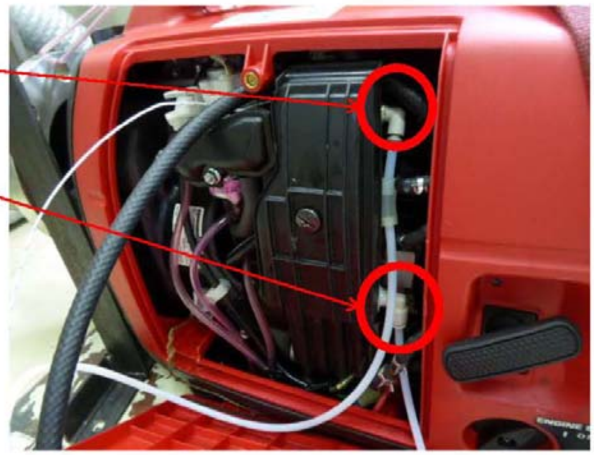
The dilution tunnel did not function properly for our small carbureted generator.

→ Vacuum was created where the tunnel connected to the intake*

As a solution, nitrogen was injected directly to the air cleaner chamber.

O_2 concentration measurement points

Nitrogen injection



This set-up works for generators operated with exhaust volumes of 100cc, 5000 rpm at WOT.

*The larger FI generator also had the vacuum issue but the overall impact was negligible.

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Dilution Tunnel Test – O_2 Measurement

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1) O_2 Measurement

Concern: Measuring the O_2 effected CO emissions

Solution: The O_2 concentration was not measured when the CO emission measurement was taken

→Unable to establish precise O_2 concentration when CO is measured

2) O_2 Stability

Concern: When the engine's RPM is not stable, the O_2 concentration is not stable

→ Happens at low loads and low O_2 concentration levels

Solution: An average CO emission was calculated over a period of 4 minutes.

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1. Dilution Tunnel Test Overview
2. Definitions
3. Evaluation of Dilution Tunnel Test
4. Evaluation of Emission Calculation Method
5. Recommendations

Evaluation of Emission Calculation Method (1)

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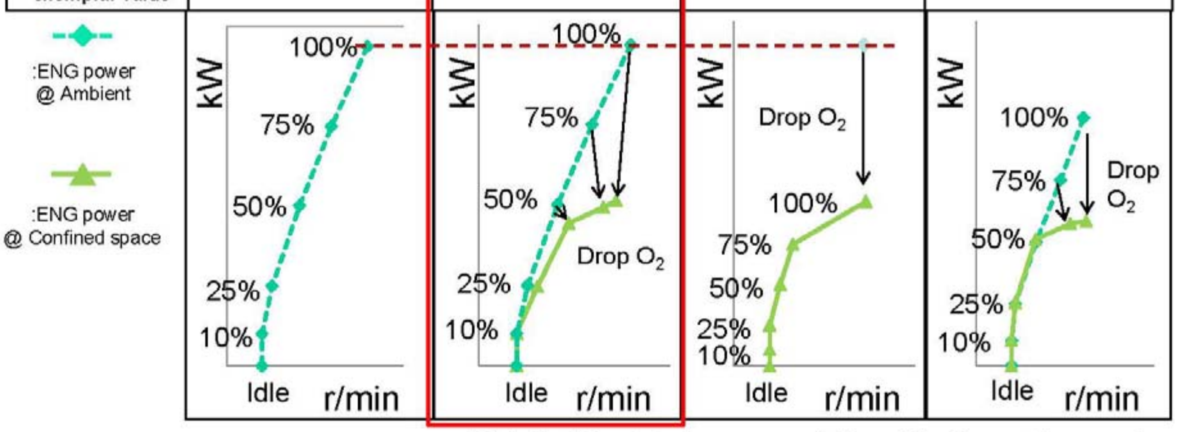
There are various interpretations on how to perform the test CO emission test. Honda evaluated 3 interpretations:

	EPA	1	2	3
	Ambient (O_2 21%)	Enclosed Space (O_2 17.5~17%)		
	Same as EPA 100% : Max engine power	100%: Max engine power @ ambient 1.Operate each mode 2.Drop O_2	100%: Max engine power @ enclosed 1.Drop O_2 2.Operate each mode	100%: Rated generator power 1.Operate each mode 2.Drop O_2
Weighted CO (g/h) *exemplar value	**1000**	**1300**	**1350**	**1450**



Note that the data is representative of the larger FI generator 15

Evaluation of Emission Calculation Method (2)

Similarly, there are various interpretations on how to calculate the total CO emission value. This value depends on the **"rated continuous power."** Honda found 5 possible ways to define "rated continuous power."

→ Measuring CO in units of g/h would avoid this confusion

	EPA			1			2			3		
	Ambient (O_2 21%)			Enclosed Space (O_2 17.5~17%)								
	Same as EPA 100% : Max engine power			100%: Max engine power @ ambient 1.Operate each mode 2.Drop O_2			100%: Max engine power @ enclosed 1.Drop O_2 2.Operate each mode			100%: Rated generator power 1.Operate each mode 2.Drop O_2		
Divided by "rated continuous power"	CO g/h	Power kW	CO g/kWh	CO g/h	Power kW	CO g/kWh	CO g/h	Power kW	CO g/kWh	CO g/h	Power kW	CO g/kWh
Weighted modal estimated engine power at ambient		4	250		4	325		4	338		3	483
Estimated max engine power at ambient		-	-		9	144		9	150		9*	161*
Max generator power at ambient	1000	-	-	1300	7	186	1350	7	193	1450	7*	207*
Rated generator power at ambient		-	-		6	216		6	225		6*	242*
Weighted modal estimated engine power at enclosed		-	-		3	433		2	675		3	483

*Revision 08-27-15

Please note these values are not based on actual performance but used as an example only 16

1. Dilution Tunnel Test Overview
2. Definitions
3. Evaluation of Dilution Tunnel Test
4. Evaluation of Emission Calculation Method
5. Recommendations

Recommendations

1) Use g/h instead of g/kWh for the CO emission rate
2) Add a "Definition Section"
3) Equipment specifications need to be determined
4) O_2 measurement method need to be determined

QUESTIONS

Dilution Chamber Test Method for Determining Portable Generator CO Emissions in a Reduced Oxygen Environment

TTi Proposed Dilution Chamber Test Method:

1. **Determine Generator Maximum Continuous Output Power[1].** Ensure test labs are at ambient conditions (Dry Bulb Temperature 75-80°F, Oxygen 20.8-21%, Barometric Pressure 950 - 1050 hPa, Relative Humidity 0-75%). Apply a load to the Generator while monitoring the voltage and frequency. Load should be increased to the maximum available Observed Wattage output without causing the voltage or frequency to fall out of tolerance. When the maximum wattage is reached, the unit should be allowed to warm up until operating temperature has stabilized. The unit is considered to be at temperature stabilization when the engine oil temperature varies by less than 2°C (4°F) over 3 consecutive readings taken 15 minutes apart. As the unit warms up, the load may need to be adjusted to maintain maximum output wattage without exceeding voltage or frequency tolerances. Record voltage, amperage, frequency, wattage, oil and ambient air temperature and maximum applied load several times during the test to show trends.
2. **Precondition Nitrogen Chamber.** Precondition chamber and ensure environmental conditioning equipment can maintain internal chamber air temperatures to below 100 °F.
3. **Precondition Engine & Generator.** With open ventilation within the chamber, start the engine and apply 100% maximum capable load to the generator until the oil & spark plug temperatures have stabilized. The engine temperature is considered to be at temperature stabilization when the engine oil & spark plug temperatures vary by less than 2°C (4°F) over 3 consecutive readings taken 15 minutes apart.
4. **Prepare Nitrogen Chamber.** Turn off the engine and clear any residual exhaust air to ensure ambient Oxygen conditions within the chamber. Seal the chamber so that no external air is allowed to enter into the chamber. Initiate air mixing equipment to ensure consistent results as necessary.
5. **Start & Apply Load to Generator.** Start the engine and apply 100% maximum capable load to the generator until the oil & spark plug temperatures have stabilized. The engine temperature is considered to be at temperature stabilization when the engine oil & spark plug temperatures vary by less than 2°C (4°F) over 3 consecutive readings taken 15 minutes apart.
6. **Adjust Nitrogen Flow.** Begin to flow Nitrogen into chamber and adjust flow rates until desired Oxygen Concentration is achieved. Continuously monitor the chamber internal air CO concentration levels to ensure they remain below 400ppm.
7. **Measure Engine Emissions at Low Oxygen**. After Oxygen concentration is stable to the desired level, begin emissions sample for 2 minutes per EPA 40 CFR 1065
8. **Remove Load to Generator.** Once data collection has completed for the desired Oxygen Concentration level, remove the load from the generator and allow the unit to continue running.
9. **Repeat at Various Oxygen Levels.** Repeat steps 6 – 8 for Stabilized Oxygen Concentration levels of 20±0.25%, 19±0.25%, 18±0.25%, & 17±0.25%.
10. **Test Complete.**

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DEFINITIONS

[1]**Maximum Continuous Output Power** is determined by the following:

- The voltage shall be within 10% of the nameplate rated voltage and the frequency shall be within +/-5% of the nameplate rated frequency for all loads from no-load to maximum wattage.

- The portable generator shall be prepared and started in accordance with the operating instructions. Start the unit and measure the voltage and frequency at no-load. If the voltage or frequency is out of tolerance a minimum adjustment shall be made to the unit to bring it into tolerance. Typically, the no-load frequency is adjusted to be between 60 and 63 Hertz.

- Load is to be applied to the unit while monitoring the voltage and frequency. Load should be increased to the maximum available Observed Wattage output without causing the voltage or frequency to fall out of tolerance. When the maximum wattage is reached, the unit should be allowed to warm up until operating temperature has stabilized. The unit is considered to be at temperature stabilization when the engine oil temperature varies by less than 2°C (4°F) over 3 consecutive readings taken 15 minutes apart. As the unit warms up, the load may need to be adjusted to maintain maximum output wattage without exceeding voltage or frequency tolerances. Record voltage, amperage, frequency, wattage, oil and ambient air temperature and maximum applied load several times during the test to show trends.

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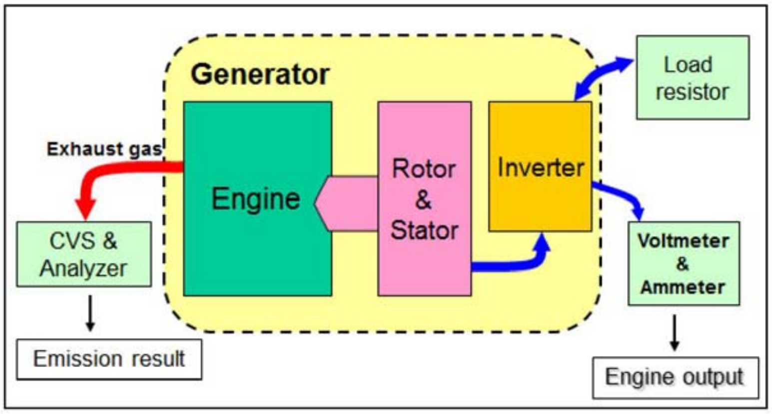
Emission Test Using a Load Bank

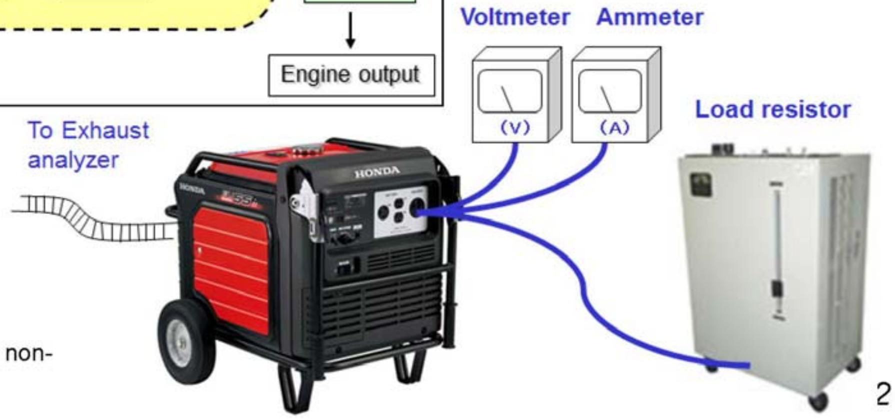
1

Equipment Set-up

The generator is connected to a Load Resistor, Voltmeter, Ammeter and Exhaust Analyzer per the diagram below.



Please note that Honda refers to 40 CFR 1065, General Test Procedures, for recommended measurement equipment.



* This method also works for non-inverter generators.

2

Equipment

The load resistor is controlled by a test employee outside of the controlled room. The exhaust gas analyzer, Constant Volume Sampler (CVS) and the voltage/current readings are outside of the controlled room. Honda uses the exhaust gas analyzer of the CVS system to avoid variation of the air/fuel ratio.

Exhaust Gas Analyzer & CVS

Voltage and Current read out

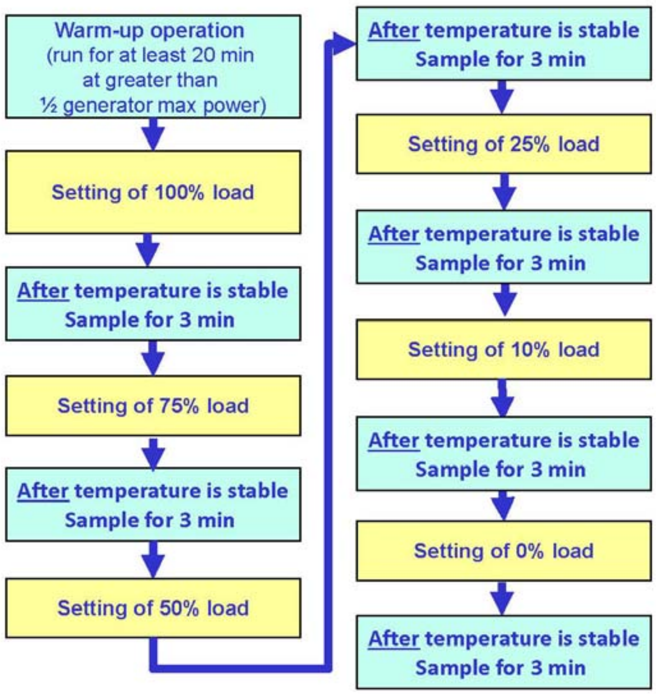
Load Resistor

It is very important to use a Load resistor that can do precise measurements similar to this slide adjuster. Precise loads are needed for each measurement point (100%, 75%, 25%, 10%, 0% load).

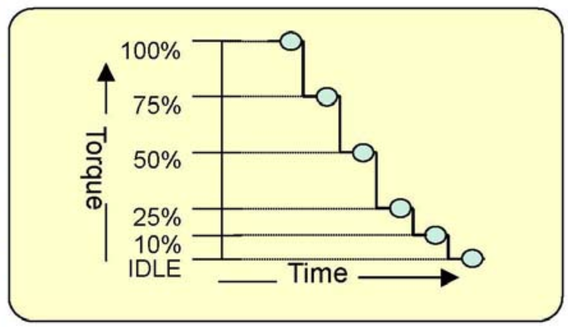
3

Emission Measurement Procedure

Honda uses Test Cycle A, G2 steady state, intermediate speed discrete modal (6 mode). Emissions are continuously measured throughout these modes. It is crucial that oil temperature measurement is monitored throughout the testing process.



Mode point	Load	Comment
1	100%	Maximum load
2	75%	75% of maximum load
3	50%	50% of maximum load
4	25%	25% of maximum load
5	10%	10% of maximum load



4

Honda's Method of Max generator Power

HONDA
The Power of Dreams

Honda suggestion of Max generator power definition is based on ISO8528-8 3.4 and ISO8528-7.3.2.
So, following few pages are one case (reference) of Honda method to determine Max generator power.

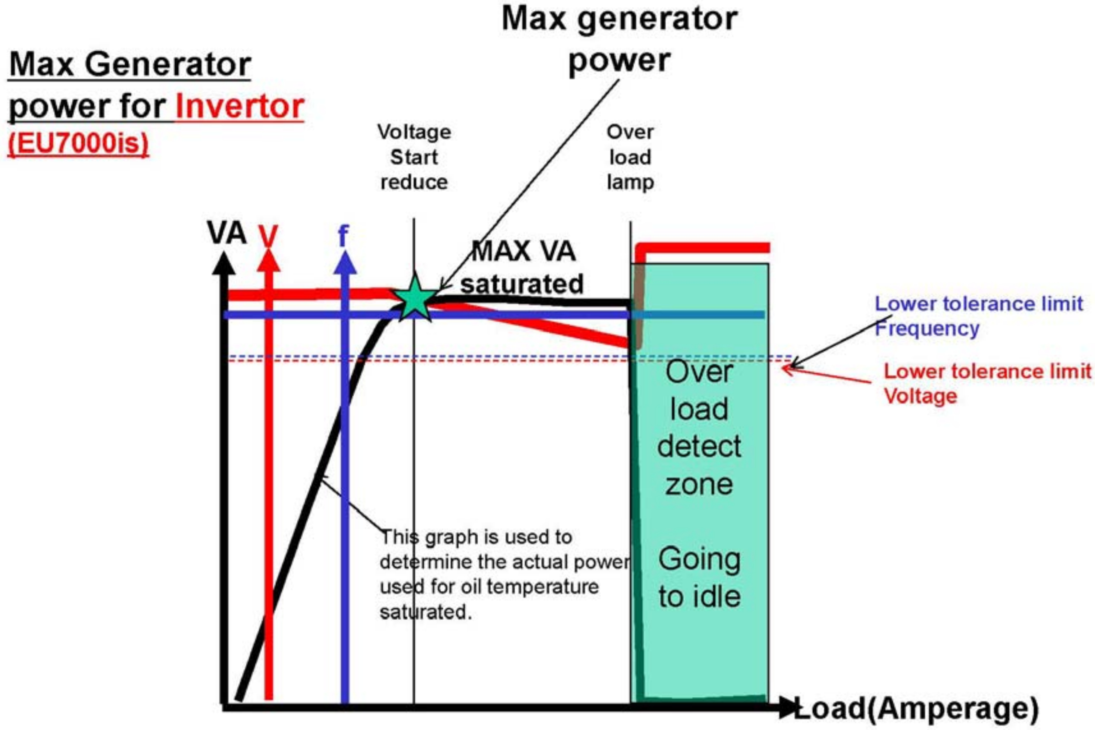
Parameter	Definition
New ISO 8528 maximum load ISO 8528-8 "Reciprocating internal combustion engine driven alternating current generating sets -- Part 8: Requirements and tests for low-power generating sets" – Draft of FDIS This draft will be New ISO8528 and ENISO8528	·ISO8528-8 3.4 Maximum power (MAX) power given by multiplying the current and voltage that the generating set is capable of delivering for **at least 5 minutes** under the following voltage and frequency that the generating set is capable of delivering over a short period within the voltage and frequency limits. Note 1 to entry: Prescribed output **voltage shall be within ±10% of the rated voltage** and prescribed output frequency shall be within ±8% of the rated frequency Note 2 to entry: The protective device shall not be activated for a period of 5 minutes and the overload conditions shall meet the requirements of sub clause 6.4. The minimum ratio between the power rating (COP) and the maximum power (MAX) shall be **Prated/Pmax ≥0.75**

Ref. ISO 8528-8 3.4

1

Honda's Method of Max generator Power

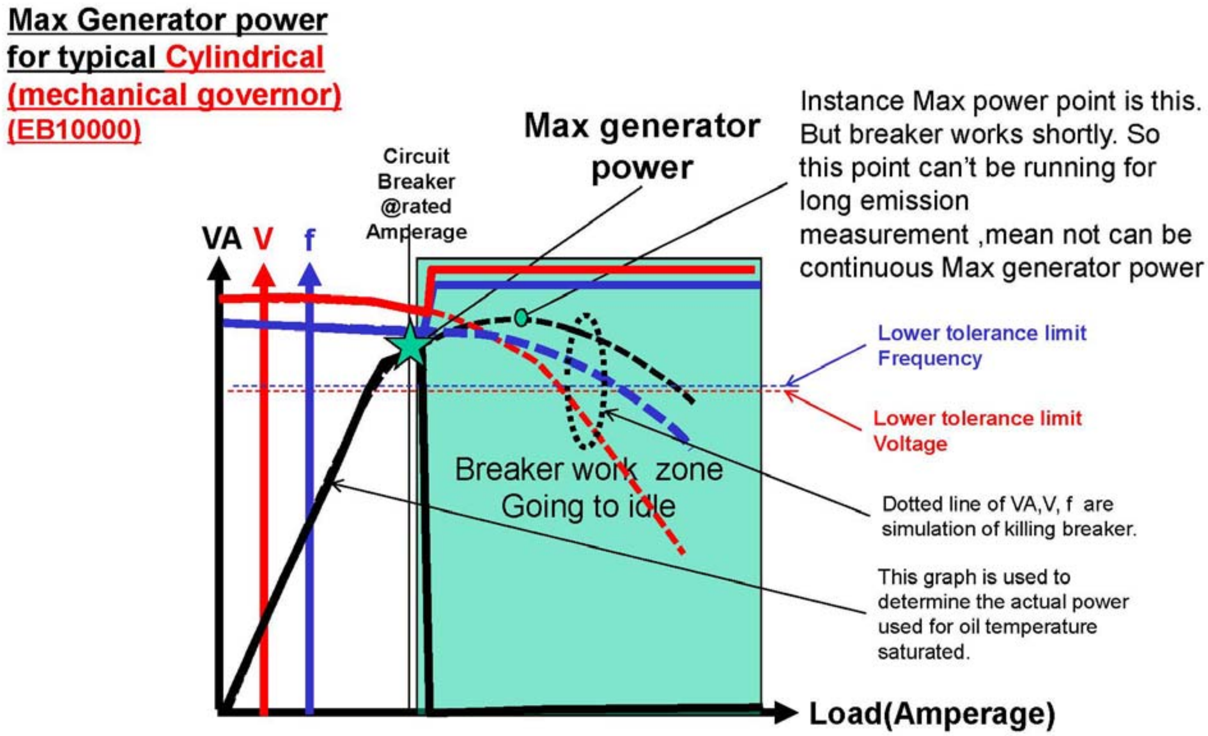
HONDA
The Power of Dreams



2

Honda's Method of Max generator Power

HONDA The Power of Dreams



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